Standard for Sand Filters

Definition

Sand filters are structural devices that treat the volume of runoff from the water quality storm (WQV) and return the flow through an underdrain back to the conveyance system. Sand filters use physical straining, solids settling, and adsorption processes to reduce pollutant concentrations in stormwater.

Purpose

The purpose of sand filters is to reduce pollutant concentrations in stormwater to acceptable levels. They usually are used to treat runoff from impervious areas.

Conditions Where Practice Applies

Sand filters are ideally suited to treat runoff from small impervious areas with low sediment loading such as rooftops, parking lots and urban areas with drainage areas up to 5 acres. In general, surface sand filters are *not* recommended where high sediment loads are expected, since sediment will clog the filter. Sand filters require a small area (2-3% of the impervious drainage area), and are viable for highly urban areas. In extended cold periods, sand filters will freeze and no filtering will occur.

Design Criteria

Note: Additional sand filter design criteria is available within the revised Standards for Soil Erosion and Sediment Control in New Jersey, Runoff Treatment Standards.

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Overview:

Sand filters generally consist of four basic design components:
1. an inflow regulator that diverts the WQV into the system and bypasses exceeding flows
2. a pretreatment system that settles out coarse sediments
3. the sand filter bed
4. an outflow structure that returns filtered effluent back to the stormwater conveyance system and handles flows that exceed system capacity.

Most sand filters are designed off line where the WQV is diverted from the main conveyance system. Some are designed on line where the entire volume of stormwater runoff will be directed at the filter. Figures 1 and 2 illustrate the most typical types of sand filters.

Surface Sand Filter (Figure 1)

The surface sand filter is comprised of two sections- a sedimentation area for pretreatment and a filter bed consisting of 18 – 24 inches of sand which treats runoff before returning it to the conveyance system via the underdrain. A variation on this design is the organic sand filter, where a layer of compost or organic peat lies on top of a thinner sand layer for enhanced removal of pollutants.

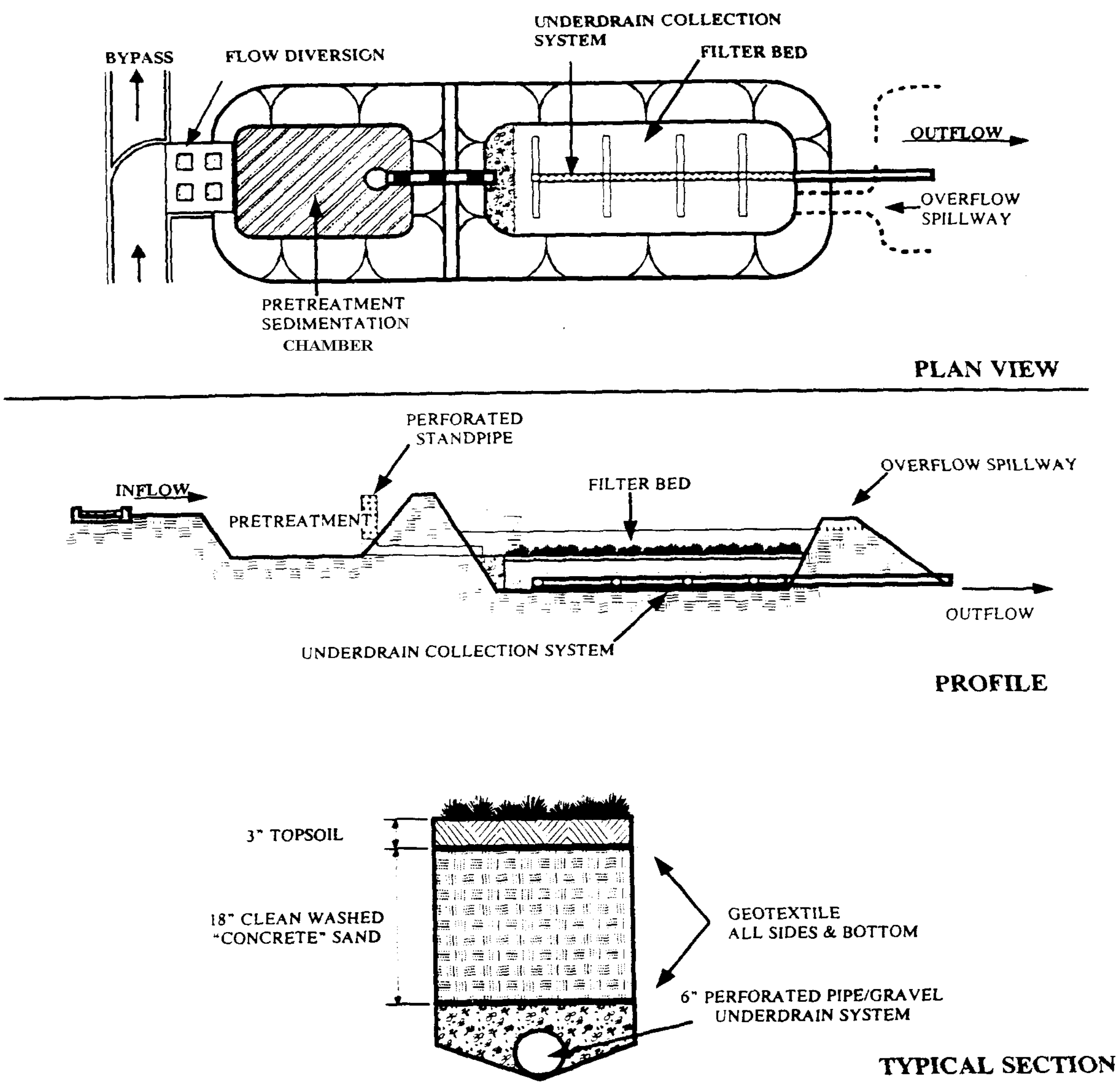

Figure 1. Surface Sand Filter Source: Center for Watershed Protection

Perimeter Underground Sand Filter (Figure 2)

The perimeter underground (sometimes called 'vault') sand filter is used in highly urbanized areas where space is a major concern. The system is placed subsurface, usually along the edge of a large impervious area. Flow enters through surface grates and drops to the sedimentation chamber. From there, it flows over a weir to the sand filter. Variations on this design can include an inflow pipe conveying stormwater into the sedimentation chamber in addition to or in lieu of the inlet grate system.

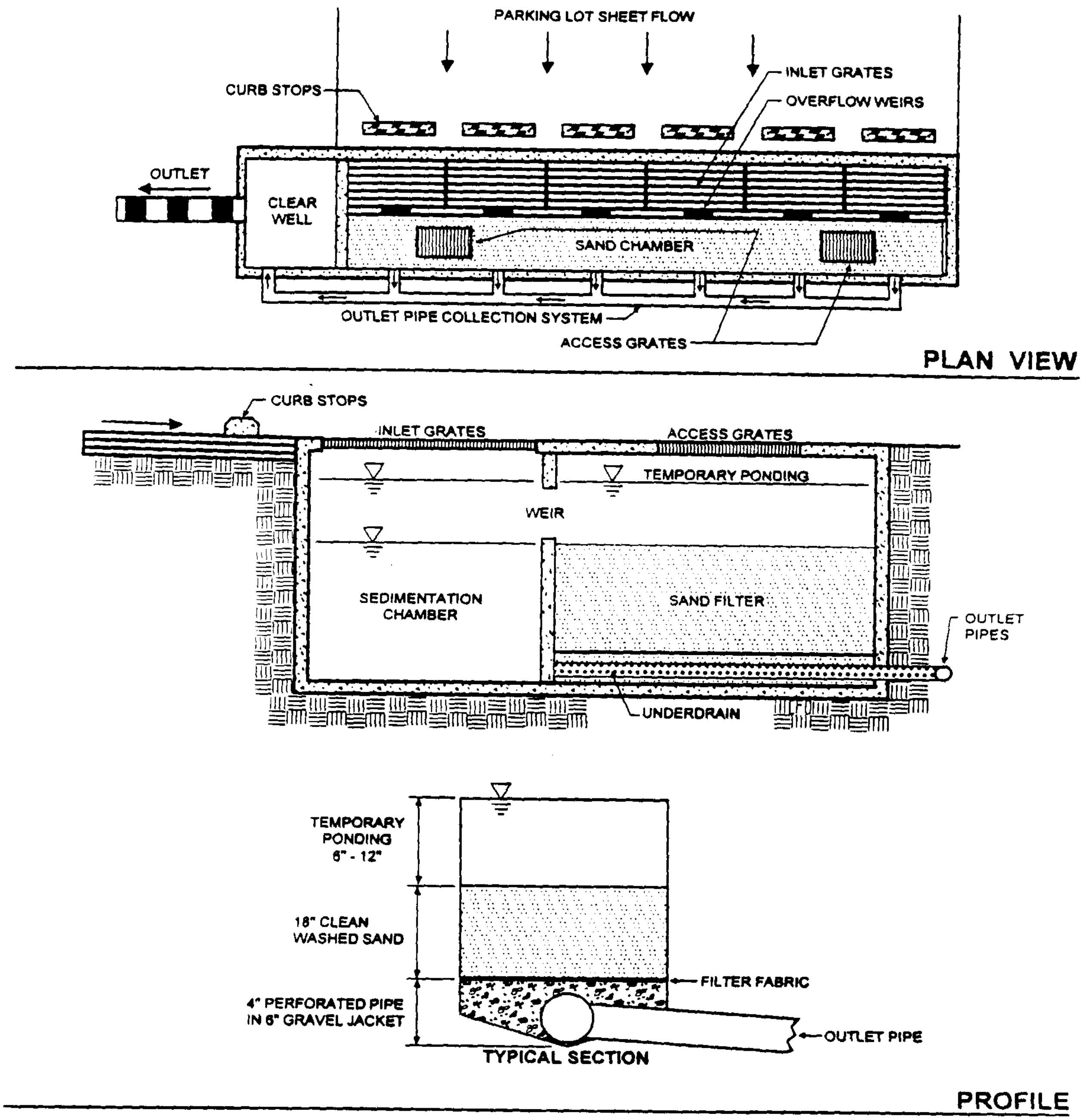

Figure 2. Perimeter Underground Sand Filter
Source: State Maryland Dept. of Environment, 1998

Sizing Procedures for Sand Filters:

Sizing sand filters is usually a straightforward process. Listed below is the sizing procedure for each design variation.

1. Compute the water quality volume (WQV) expected from the water quality design storm (1.25 inches in two hours- see Chapter 7). Only the runoff from impervious surfaces is calculated in determining the WQV.

2. Calculate the peak discharge (Q_p). Use $h = \frac{Q_p^2}{2g\,(CA)^2}$ (for a circular orifice) to calculate the head above the filter diversion orifice. Set the elevation of the overflow diversion weir wall at this elevation to allow storm flows greater than Q_p to bypass the filter.

3. Size the sand filter bed surface area (A_f) using Darcy's Law:

$$(A_f) = WQV \times (d_f)/[k \times (h_f + d_f)(t_f)]$$

where:

d_f = sand filter bed depth, ft.
k = coefficient of permeability for sand bed, ft./day
h_f = average height of water above the sand bed, ft.
t_f = time required for the WQV to filter through the sand bed

- d_f can vary depending on the site conditions but should be between 18 – 24"
- h_f will also vary depending on the site conditions, but should not exceed 6 feet
- 40 hours is recommended for t_f
- k recommended for sand is 3.5; for sand/peat mix is 2.75; for compost is 8.7

4. Size the sedimentation basin surface area (A_s):

A_s = 0.066 x WQV ft² where the percentage of impervious area is <75%
A_s = 0.0081 x WQV ft² where the percentage of impervious area is > 75%

- the length to width ratio of the basin should be 2:1 or greater
- inlet and outlet structures should be located at extreme ends of the basin
- the basin bottom shall have a minimum depth of 3 feet to minimize resuspension and turbulence
- the basin bottom grade shall be 0.0 to 0.002 ft/ft

5. Compute the required minimum storage within the practice:

$$V_{min} = \tfrac{3}{4} \times WQV$$

SURFACE SAND FILTER Specifics:

- Compute the water volume within the filter bed
  (V_f) $=A_f \times d_f \times$ (0.4 porosity factor for sand/gravel perf.pipe)
- Compute the temporary storage volume above the filter bed ($V_{f\ temp}$) = $2 \times h_f \times A_f$
- Compute the temporary storage volume required for the dry settling basin (V_s)
- V_{min} – (V_f + $V_{f\ temp}$). Note: V_s should be approximately to 50% of V_{min}. If not, decrease h_f and recompute.
- Compute height (h_s) in settling basin chamber. $h_s = V_s/A_s$.
- Check to make sure that $h_s > 2 \times h_f$ and $h_s \geq$ 3'. If not, adjust h_f and repeat procedure.

Pretreatment Components:

- Dry pretreatment basin
- Minimum volume = ¾ x WQV: split between volume within filter bed (voids), volume above filter bed, and volume within pretreatment basin.
  Perforated standpipe with orifice sized to release volume over 24 hours. Note: The size and number of perforations depends on the release rate necessary to achieve 24 hour detention.
- Overflow weir within the sedimentation chamber is set at design treatment volume, sized to pass 2/3 of WQV peak flow. Overflow weir within sand bed chamber set at design treatment volume, sized to pass 1/3 of WQV peak flow. This ensures at least partial treatment for flows exceeding ¾ x WQV.

UNDERGROUND and PERIMETER SAND FILTER Specifics:

- Compute the water volume within the filter bed (V_f) = $A_f \times d_f \times 0.4$
- Compute the minimum wet pool volume in the settling basin (V_f) = $A_s \times$ 2' minimum.
- Compute temporary storage volume required (V_{temp}) = V_{min} – (V_f + V_w)
- Compute the total surface area of both chambers ($A_f + A_s$)
- Compute the temporary storage height (h_{temp}) = V_{temp}/ ($A_f + A_s$)
- Check to make sure that $h_{temp} > 2 \times h$, (from Darcy's equation). If not, decrease h_f and recompute.

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Pretreatment Components:

- Wet sedimentation chamber:
  Wet volume (V_w) = $A_s \times$ depth (3' min. permanent pool storage)
- Total minimum volume = 3/4 x WQV: Split between volume within filter bed (voids), wet volume within sedimentation chamber, volume above wet volume, and volume above sand bed.

- Elevation of overflow weir = (3/4 x WQV) elevation sized to pass 100% of 10 year flow. The main collector pipe for sand filters should be constructed at a slope of 0.5% to 1.0%. Observation and clean-out pipes must be provided for all underdrain conduits.

A dewatering gate valve should be included if possible in underground sand filters at the top elevation of the sand filter bed for maintenance if the bed becomes clogged and retains water.

Considerations

No runoff should enter the sand filter bed until the upstream drainage area is completely stabilized and site construction is completed.

The top of the sand filter bed must be constructed completely level. Allowance for settlement after initial construction is required. Overflow weirs, multiple orifices, and flow distribution slots must be constructed completely level to ensure adequate distribution of design flows.

Underground sand filters should always be constructed completely watertight, especially if used in ‘hotspots’ or over extremely sensitive ground water conditions.

Operations and Maintenance

Sufficient access to the basin in surface sand filters for maintenance is necessary. An access ramp to the facility should be provided with crushed stone at a maximum slope of 2%. Provisions must be made ahead of time for the removal, disposal or re-use of sediment (both from the sedimentation basin/chamber and the sand bed).

Inspection Item	Inspection Frequency	Disposition
Debris Cleanout: Inlets and outlets clear? Filter clear?	Quarterly	Identify areas requiring cleanout and severity of buildup
Filter Bed Chamber: Evidence of clogging? Sediment buildup <1” ? Oil/grease sources impacting filter?	Semi-annually	Identify clogged filter bed, source area contributions and actions required
Sediment Chamber: Sediment buildup rate? Water depth?	Semi-annually	Identify leaking chamber in underground types, identify corrective actions
Structural Components: Structural deterioration? Inlet, outlet pipes, grates, OK? Spalling or cracking of concrete?	Annual	Identify problems and corrective actions required
Outlets/overflow weir: Clogging of outlet? Downstream erosion? Underdrain pipe failure?	Annual	Identify problems and corrective actions required

Source: Adapted from Claytor & Schueler, 1996 Design of Stormwater Filtering Systems